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PEGMATITE, SILEXITE, AND APLITE OF NORTHERN NEW YORK[1]

WILLIAM J. MILLER
Smith College, Northampton, Massachusetts

INTRODUCTION

During twelve seasons of field work in the Adirondack Mountain region of New York, the writer has made many hundreds of observations on bodies of pegmatite, quartz (silexite), and aplite. Certain of the phenomena long proved to be very puzzling, and more recently it has become evident that some generally accepted interpretations of such phenomena are not satisfactory when applied to many of the occurrences in the Adirondack region. While engaged in the detailed geologic mapping of the Lyon Mountain quadrangle, the writer was soon impressed by the exceptional opportunity for a careful study of the pegmatite, quartz (silexite), and aplite bodies which are there so wonderfully exhibited in countless numbers. Many detailed notes were taken and sketches were made. The North Creek quadrangle, surveyed by the writer some years ago,[2] was also revisited for the purpose of making further observations on certain pegmatites there so well exhibited. In this paper the discussions deal almost entirely with the Lyon Mountain and North Creek quadrangles.

PEGMATITE, SILEXITE, AND APLITE IN THE GRANITES OF THE LYON MOUNTAIN QUADRANGLE

The granites.—Several varieties of granite and granitic syenite constitute the main bulk of the rocks of this district. Among these the variety of chief interest in the present discussion is a fine to medium-grained, usually pink rock varying from a true granite through granitic syenite to quartz syenite or even quartz diorite. In the more typical specimens of granite dark minerals, except magnetite, are either almost wholly absent, or they make up less than 5 per cent of the rock. Thin sections of the typical granites contain microperthite, 45 to 70 per cent; quartz, 25 to 35 per cent; oligoclase, 5 to 25 per cent; usually microcline, 5 to 15 per cent; magnetite, ½ to 2 per cent; and usually less than 2 per cent of one or more of the following: titanite, hornblende or pyroxene, biotite, zircon, apatite, and hematite (stains). Locally, probably owing to incorporation of material from older basic rocks, dark minerals, including hornblende, monoclinic pyroxene, and biotite, are fairly conspicuous. A magmatic flow-structure foliation is generally more or less well developed in the granite, but some portions of the rock which are almost free from dark minerals exhibit practically no foliation to the naked eye.

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[1] Published by permission of the state geologist of New York.

[2] W. J. Miller, *N.Y. State Mus., Bull. 170.*

The writer proposes to call the rock just described the "Lyon Mountain granite" because of the excellent exposures in and near the village of Lyon Mountain. This rock is also extensively developed on Johnson Mountain, Duncan Mountain, and in the valley of the Saranac River. The Lyon Mountain granite is perhaps the most conspicuous member of Cushing's "Saranac formation."[1] This Lyon Mountain granite contains a truly wonderful display of pegmatite and quartz (silexite) in the form of dikes, segregation masses, and inclusions. In many places the granite is very highly pegmatized. All the numerous magnetic iron-ore deposits, including those of the Lyon Mountain mines, occur in this granite. The structure and origin of these deposits are discussed by the writer in another paper.[2]

There is considerable field evidence to show that the Lyon Mountain granite grades into and is only a facies of a coarse-grained rock which the writer proposes to name the "Hawkeye granite" because of its excellent outcrops just east of Hawkeye post-office. In thin section the rock from the type locality shows microcline, microperthite, and quartz in about equal amounts; 8 to 10 per cent of oligoclase to albite; and small quantities of biotite, apatite, zircon, magnetite, chlorite, and secondary calcite.

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[1] H. P. Cushing, *N.Y. State Mus., Bull. 95* (1905), pp. 299–303.

[2] W. J. Miller, *N.Y. State Mus. Bull.*, on the geology of the Lyon Mountain quadrangle soon to appear.

At the summit of Lyon Mountain the rock contains 2 or 3 per cent each of hornblende, diallage, and bronzite. The feldspar and quartz crystals are usually from one-fourth of an inch to an inch long. Where fresh the rock is greenish gray. It weathers to a light brown. A gneissoid structure is generally more or less well developed, though considerable bodies of the rock may show it scarcely at all. The Hawkeye granite is extensively developed in Silver Lake Mountain and in the southeastern half of the great mass of Lyon Mountain.

More locally the Lyon Mountain granite grades through granitic syenite into quartz syenite and even into quartz diorite.

Silexite in the granites.—The term "silexite" is elsewhere proposed[1] by the writer for any body of pure or nearly pure silica of igneous or aqueo-igneous origin which occurs as a dike, segregation mass, or inclusion within or without its parent rock. So-called "quartz dikes" are included under "silexite."

Hundreds of silexite masses were observed in the granites of the Lyon Mountain quadrangle. They are most abundant by far in the Lyon Mountain granite. The evidence that they are not true veins is decisive. None of them ever shows crustification, and many of them grade into true pegmatite. Thus at the summit of Duncan Mountain and also just south of the southern summit of Alder Brook Mountains, where both pegmatite and silexite are grandly exhibited in the large, bare ledges of Lyon Mountain granite, one may observe every possible gradation from typical, moderately coarse-grained pegmatite, consisting mostly of pink potash feldspar and some quartz, to about equal amounts of feldspar and quartz, to mostly quartz, with some scattering crystals of feldspar, and to practically pure silica (silexite). Most of the silexite contains 1 or 2 per cent of feldspar in the form of small crystalline masses with rather blurred contacts against the silica. All the facies just mentioned occur on Duncan Mountain, not only in the form of dikes more or less parallel to the foliation of the granite, but also often as irregular bunches or lenses crudely parallel to the foliation, the original masses in the latter cases apparently having been broken up, pulled apart, and the pieces more or less shifted after they were developed, by movements in the granite magma, which still possessed a considerable degree of fluidity. Such breaking up and shifting of pegmatite and silexite masses appear to have been most notably true of the silexite. Many of the later pegmatite dikes (below described) exhibit no such phenomena. We are led to conclude, therefore, not only that many masses of practically pure silica (silexite) separated from the granite magma well before many of the ordinary pegmatites, but also that the separation of the silica took place well before the complete solidification of the granite magma. Accordingly those masses of silexite which developed early (probably as segregation masses) and were broken up and more or less shifted in the magma are to be regarded as inclusions in the granite.

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[1] W. J. Miller, *Science*, in a number soon to be issued.

The following sketches (Figs. 1, 2, 3) of portions of the ledges at the summit of Duncan Mountain will suffice to make clear the foregoing conclusions. Figure 1 shows seven fragments of silexite. Evidently they represent portions of one or more masses which were broken up and strung out in the magmatic current. The wrapping of the magmatic flow-structure about the fragments is very evident. Contacts of the silexite against the granite are sharp. That these fragments are true inclusions of silexite which must have developed (probably by segregation) well before the final consolidation of the granite magma is strongly supported by the undoubted inclusions of both Grenville strata and an old gabbro which, in the Lyon Mountain district, have been observed to bear exactly similar relations to the granite (see Fig. 5). Unlike the Grenville and gabbro inclusions, however, the fragments of silexite are not distinctly older than the granite. They are early facies of the pegmatitic masses which developed during the intrusion of the granite and probably after the magma had come nearly to rest. Thus other nearby ledges of granite at the top of Duncan Mountain show distinct inclusions of silica which contain varying amounts of feldspar, though seldom more than 15 or 20 per cent. Usually with increased feldspar content the contacts against the granite are less sharp. Also in many cases silica, usually with a small content of feldspar, still exists in rather distinct dikelike form with only fairly sharp contacts against the granite. Again, in many cases, practically pure silexite and ordinary pegmatite, the one grading into the other, occur in the same inclusion or dike. Just south of the southern summit of Alder Brook Mountains the large bare ledges contain many pegmatite and silexite masses which exhibit the features just described, the pegmatite and silexite there often grading into each other. Some of these cut the granite very irregularly in true dike form without very sharp contacts. Phenomena like those above described have been observed in many parts of the Lyon Mountain quadrangle.

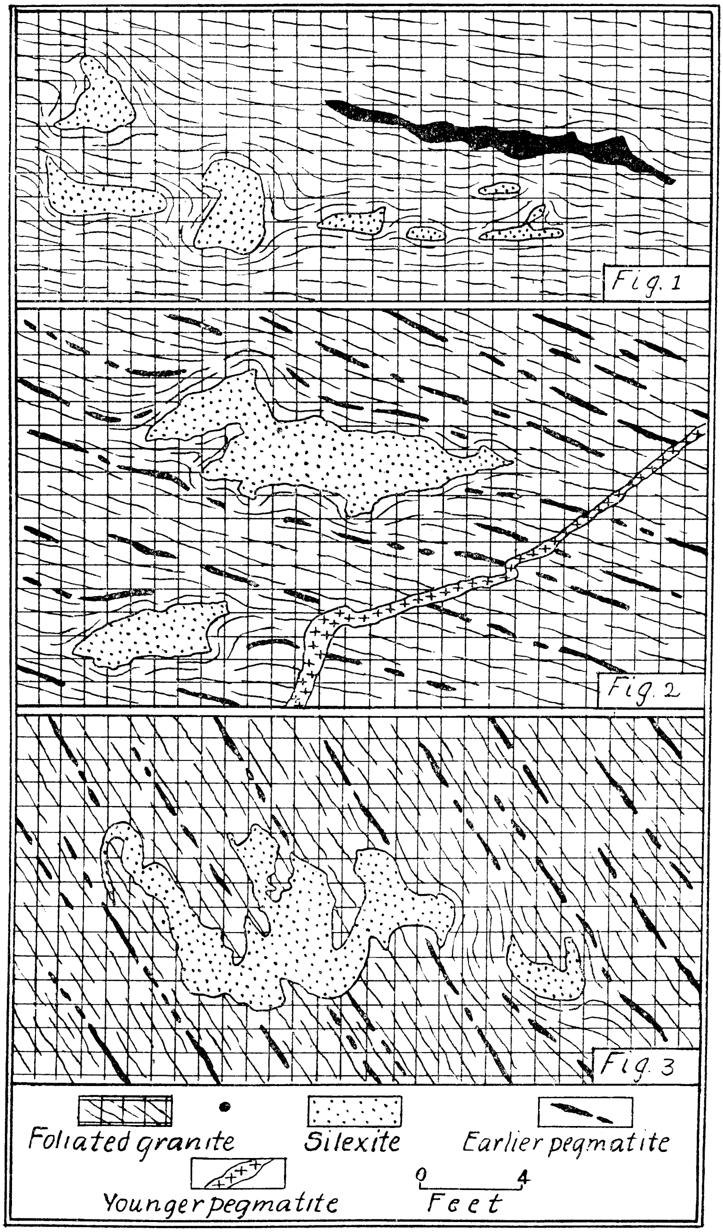
Figure 2 shows two larger masses of nearly pure silica (silexite) with their long axes parallel to the fluxion structure of the inclosing granite, with very distinct magmatic flow-structure foliation curved about them, and with sharp contacts against the granite.

A more exceptional case is shown by Fig. 3. The larger mass of silexite is exceedingly irregular in shape, and it locally contains considerable feldspar. Both inclusions seem to lie almost at right angles to the foliation of the granite, though it is quite possible that this ground-plan sketch does not actually represent the position of the whole original larger mass of silexite from which the inclusions were derived in the granite. Fluxion structure is locally distinctly curved on one side of the smaller fragment of silexite, and also between it and the larger fragment.

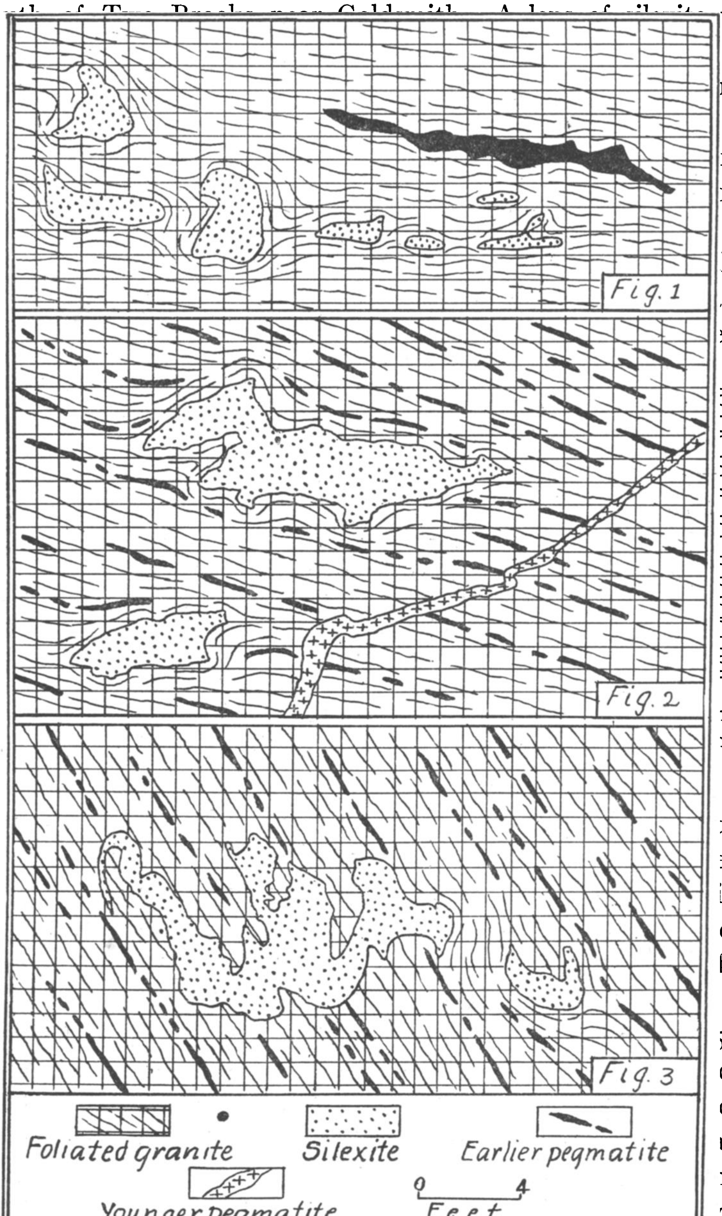
Figure 4 shows a very interesting silexite dike unusually thick at one end and with five clearly defined dikelike branches cutting the granite at the other end. The silexite contains not over 10 per cent of feldspar scattered through it in tiny masses. Contacts against the granite are only fairly sharp, and the foliation of the granite nowhere curves around the silexite. This is quite certainly a true dike of silexite, and it was formed later than the silexite of Figs. 1, 2, and 3, so it was not pulled apart by the granite magma which had already nearly or quite consolidated.

A small lens of silexite occurs as a distinct inclusion with sharp contacts in one of the later pegmatites (see below) on the low ridge one mile east-northeast of Goldsmith.

A mass of nearly pure silica (silexite) which demonstrably formed well before the solidification of the medium-grained granite which contains it occurs on the ridge one mile northeast of the



FIGS. 1, 2, and 3.—Sketches of portions of the ledges at the summit of Duncan Mountain in the Lyon Mountain quadrangle showing the relations of silexite and pegmatite to the foliated granite.



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Some fine examples of crudely lens-shaped masses of practically pure silica (silexite) have been observed by the writer in the Blue Mountain quadrangle in syenite, granite, and mixed gneisses apparently always parallel to the foliation of the inclosing rock. In one case a small dike of pegmatite sharply cuts a long, narrow lens of silexite.

Earlier pegmatites.—A great many masses of true pegmatite of early origin lie in the Lyon Mountain granite parallel to its foliation. The mineral content of these early pegmatites is remarkably simple, by far the greater number of them consisting very largely of quartz and potash feldspar (mostly microcline), some microperthite and oligoclase, and a little biotite. Some pegmatites, probably to be classed with the early ones, though not with the earliest, carry more or less magnetite, hornblende, or pyroxene, but these minerals appear to have been largely or wholly derived from the old dark gneisses and gabbro which were invaded by the granite. Minerals so common to pegmatites in general, such as tourmaline, garnet, muscovite, beryl, apatite, and others, must be exceedingly rare if they occur at all. The only mineralizer,

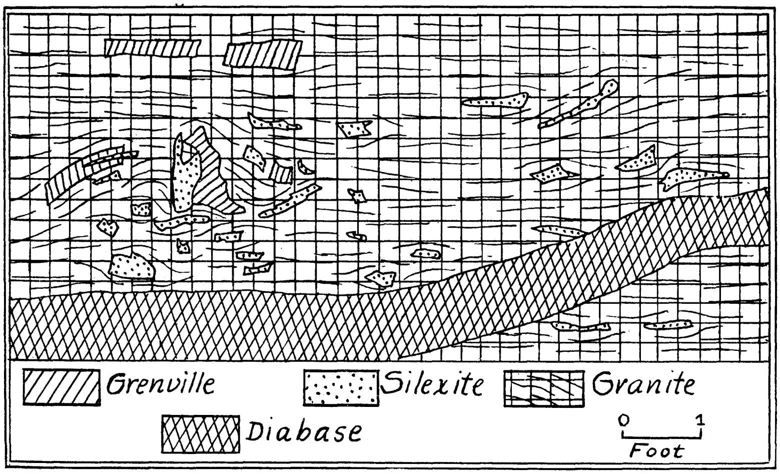

FIG. 5.—Angular inclusions of both silexite and Grenville quartzite in foliated granite at the top of the hill one-third of a mile south-southwest of Barnes Pond in the Lyon Mountain quadrangle.

therefore, which could have been present in very appreciable quantity during the crystallization of these pegmatites was water. These pegmatites rarely if ever show graphic intergrowths.

In many localities from 10 to 50 per cent of the body of the granite consists of the earlier pegmatite either in the form of narrow parallel bands from a few feet to many feet long, causing the rock to look like a coarse-banded gneiss, or as rather distinct lenses up to several feet long; or in the form of "eyes" or very short, thick, more or less rounded or elliptical lenses usually not more than a few inches long and from one-half to two or three inches thick. The long, narrow bands almost invariably grade into the granite on either side, while the lenses and eyes generally show moderately sharp contacts against the granite. The mode of occurrence of such eyes of pegmatite is fairly well illustrated by Figs. 2 and 3, the granite containing the eyes, usually exhibiting rather wavy flow-structure foliation about them. From the field relations it is quite certain that the eyes and short, rounded lenses represent long lenses or layers of pegmatite which formed before the final consolidation of the inclosing granite, and which were pulled apart and strung out parallel to the magmatic currents which were deflected around them. Their mode of occurrence and lack of sharp contacts strongly suggest that they formed during a late stage of magma consolidation, and that they are not so old as the oldest silexite masses, which are now represented as sharply defined inclusions.

M. E. Wilson,[1] in a description of the gneisses of the Laurentian highlands, notes apparently similar lenses of pegmatite and says that a "lenticular character is particularly evident in the case of the pegmatite which commonly occurs in a succession of lenses around which the foliation of the surrounding gneiss bends."

Those pegmatites which occur as long, narrow, irregular bands or strips parallel to the granite foliation, and which grade into the granite, no doubt represent the final or nearly final solidification of those portions of the granite in which they occur, and hence they are practically *in situ* and grade into the granite. Figure 1 shows a single lens of such pegmatite.

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[1] M. E. Wilson, *Amer. Jour. Sci.*, XXXVI (1913), 115.

A typical example bringing out the relation of the earlier to the later pegmatites occurs in a big ledge on the little hill just south of the mouth of Two Brooks near Goldsmith. Much of the granite contains streaks, lenses, and eyes, usually less than an inch wide and not over two feet long, of not very coarse pegmatite parallel to the foliation. This pegmatite makes up a very considerable percentage of the rock mass, with contacts varying from fairly sharp to not sharp. Cutting this combination of granite and pegmatite are several prominent later pegmatite dikes, six to eight feet wide and forty or fifty feet long, carrying equal amounts of quartz and feldspar and 10 per cent of biotite. These moderately coarse-grained later pegmatite dikes lie only partly roughly parallel to the granite foliation. This ledge calls to mind an exposure observed by the writer in the Blue Mountain quadrangle,[1] where lenses and eyes of pegmatite parallel to the foliation of a mixed gneiss are sharply cut across by a pegmatite dike of distinctly later origin.

On a little ridge one mile east-northeast of Goldsmith an outcrop shows two bands or long lenses of pegmatite parallel to the foliation of the granite and without very sharp contacts. The upper lens consists of two-thirds quartz and one-third feldspar, and it is very uniform. The lower lens is notably variable, with the different portions not sharply separated. Nearly pure silica (silexite) and typical pegmatite here developed side by side, while the inclosing granite was still somewhat fluid, as shown by the flow-structure along the lower side of the lens.

Near the road two miles east-southeast of Goldsmith a pegmatite dike, or rather a segregation mass, one foot wide and twelve feet long, which lies parallel to the foliation of the inclosing granite and grades perfectly into it, shades off into a zone of nearly pure silica (silexite) four to five inches wide toward its middle. Both the pegmatite and the silexite here developed side by side by segregation during a late stage in the solidification of the granite magma, and both pegmatite and silexite now occupy practically the place where they solidified.

A more exceptional mode of occurrence of the older pegmatites is illustrated in a ledge by an old road one mile northwest of the mouth of Alder Brook. One mass of pegmatite a few feet wide perfectly exposed for twenty feet contains orthoclase crystals up to three or four inches long, and its boundaries against the granite are sharp. A very evident magmatic flow-structure follows the details of the very irregular boundary on either side within six inches of the pegmatite, but one or two feet out the foliation is practically straight. Evidently this typical pegmatite developed unusually early, probably by segregation, perhaps as early as some of the first-formed silexite, that is to say, when the granite magma still possessed a considerable degree of fluidity.

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[1] W. J. Miller, *N.Y. State Mus., Bull. 192* (1916), pl. 10.

Later pegmatites.—As regards their mode of occurrence these later pegmatites are in most respects quite ordinary. They cut across the granite foliation at all sorts of angles, and hence they must have developed after complete, or at least almost complete, solidification of the granite which contains them. They are true dikes, generally coarser grained and usually larger than the older pegmatite masses above described. Many of them are from one to ten feet wide and from ten to fifty feet or more long. They rarely if ever exhibit graphic intergrowths. Contacts against the granite range from very sharp to moderately sharp, those with very sharp boundaries probably having developed in the solid, relatively cooler granite, while those with less sharp boundaries probably were intruded into essentially solid but relatively hot granite. Most of these dikes consist largely or wholly of pink or white potash feldspar and quartz; some contain hornblende or pyroxene, or both; some contain little or no quartz; some are almost pure quartz (silexite); a few contain scapolite, and many contain magnetite in amounts ranging from 1 to 40 or 50 per cent. With few exceptions these later pegmatites, like the earlier ones, do not contain any other minerals as well known in pegmatites in general. As pointed out below, the hornblende, pyroxene, and magnetite were almost certainly absorbed by the pegmatites from the old, invaded dark gneisses and gabbro. Apatite in small amount and many specks of titanite occur in some of the pegmatized zones of the granite in the main workings of the iron mine at Lyon Mountain village, and in somewhat greater amounts in the older workings to the east. Throughout the Lyon Mountain

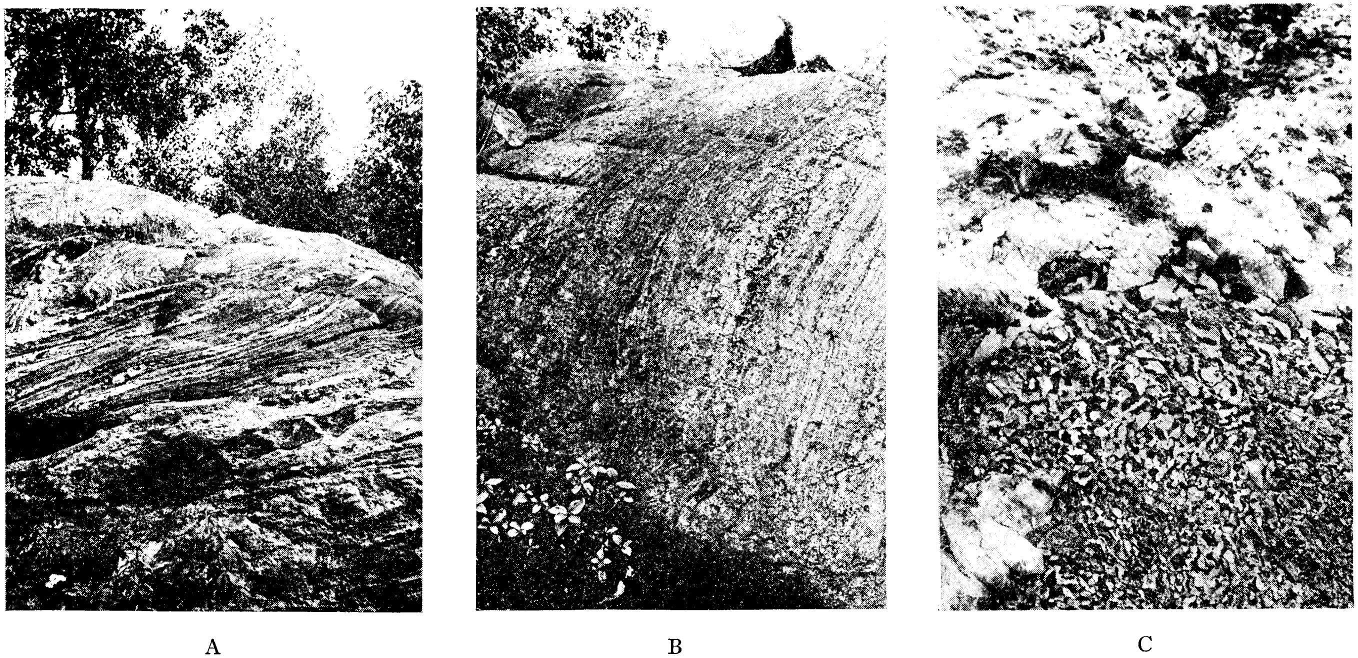
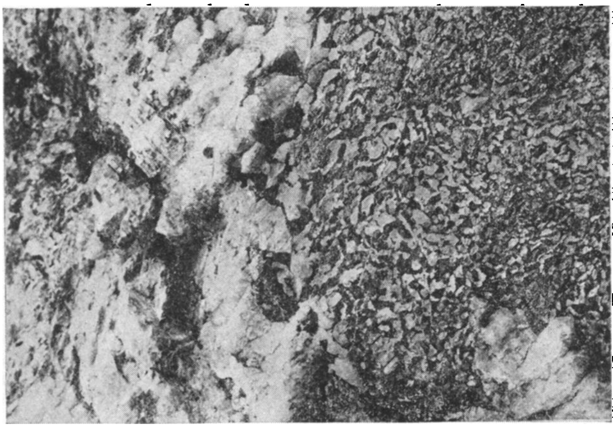


FIG. 6.—A: Part of ledge one and one-fourth miles north of Disco in the Lyon Mountain quadrangle showing hornblende gneiss (probably meta-gabbro) more or less intimately injected with Lyon Mountain granite, the resulting mixed rock being cut by pegmatite and silexite. Silexite is well shown toward the middle of the picture and pegmatite just below the middle, the latter sending dikes across a large lens of the dark gneiss. Owing to pegmatization, much of the hornblende of the dark gneiss has been changed to pyroxene. The folding toward the top was caused by magmatic movement. Width of exposure about 15 feet.

B: Part of a ledge one mile east of Goldsmith in the Lyon Mountain quadrangle. The finer-grained portion is Grenville biotitic and quartzitic gneiss intimately injected with Lyon Mountain granite. The nearly white lenses and narrow strips are pegmatite and silexite developed during an early stage of the magma consolidation, and the broad band is pegmatite which formed late in the process of the magma solidification. Width of exposure about 15 feet.

C: Near view of part of the mass of pegmatite on the western side of the gabbro stock on the hill one mile south-southeast of the Glen in the North Creek quadrangle (see Fig. 8). Lower half is quartz and black tourmaline graphically intergrown, and upper half is mostly silexite. Width of exposure about 2 feet.



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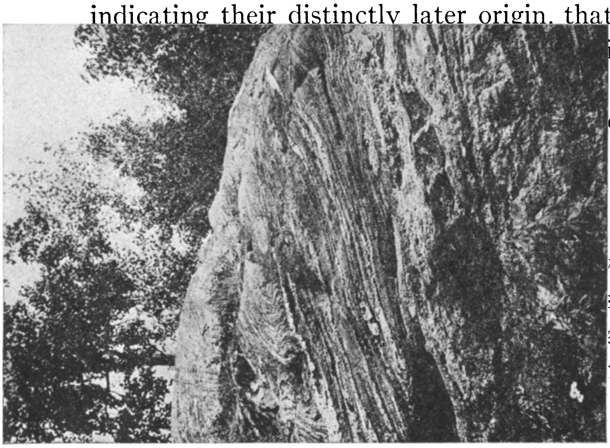

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field evidence strongly points to a derivation of these minerals from the older basic rocks by the pegmatites during their intrusion. It is significant that more or less magnetite occurs in later pegmatites at every one of the dozen or more localities from which magnetic iron ore has been mined in the Lyon Mountain quadrangle and also at many other places. A few of the more typical field occurrences will now be briefly described.

In the old mine at Russia Station pink granite and pegmatite have been intimately injected into more or less hornblende gneiss (presumably gabbro), and much of the hornblende has been altered or recrystallized into green monoclinic pyroxene, some of which occurs locally in the form of coarse granular masses several inches across. Magnetite is variably abundant in all the rocks, but it is especially so in the coarser pegmatites and the silexite of later origin which occur as rather well-defined dikes.

On the ridge one and one-half miles northeast of Standish a very irregular pegmatite dike, with a maximum width of thirty feet and traceable for one hundred and fifty feet, lies in contact with gneissoid gabbro. The pegmatite is moderately coarse to very coarse and is very rich in magnetite, many masses of which are from one to three inches across. Some tongues of the pegmatite rich in magnetite cut across the foliation of the gabbro.

On Elbow Hill two miles east-northeast of Lyon Mountain village a pegmatite dike ten feet wide and thirty feet long is directly associated with a mixture of granite and gneissoid gabbro. This pegmatite is practically a silexite, being very rich in quartz and low in feldspar, and it contains much magnetite in masses up to several inches across. The magnetite and quartz appear to be of the same generation. Some of the more ordinary later pegmatites close by contain little or no magnetite.

In one of the ore pits near the western end of the main workings at Lyon Mountain a pegmatite dike from one to two feet wide and exposed for seventy-five feet rather sharply cuts intricately mixed pink granite and hornblende gneiss. This pegmatite carries little or no quartz, but it does contain some magnetite.

By the river one mile south-southeast of Moffitsville later pegmatite cuts intricately involved granite and hornblende gneiss, the pegmatite containing bunches of green, monoclinic pyroxene and hornblende which look like inclusions up to five inches across. The pyroxene developed by recrystallization of some of the hornblende of the hornblende gneiss during the process of pegmatization for all stages, from bunches and lenses of pure hornblende, to mixtures of hornblende and pyroxene not sharply separated, to pure pyroxene, occurs in the pegmatite. Also, in thin section every stage in the transformation of the hornblende to pyroxene has been observed. This pegmatite carries some magnetite and in one portion scattering single crystals of hornblende up to one inch long, and in another portion crystals of pyroxene up to one-half of an inch long.

Aplite dikes.—Aplite dikes are locally developed often in considerable numbers in the coarse or Hawkeye type of granite. It is a striking fact that nowhere in the quadrangle were aplite dikes observed in the typical Lyon Mountain granite which contains such a profusion of pegmatites and silexites. Possibly this is because the Lyon Mountain granite is itself locally rather aplitic in character. Since the Hawkeye granite contains relatively few pegmatite and silexite masses, such could seldom be observed in their relations to the aplites in single outcrops. Few if any aplites occur in the granitic syenite or quartz syenite. It should here be recalled that the field evidence strongly points to development of the Lyon Mountain granite, Hawkeye granite, granitic syenite, and quartz syenite from a single intrusive magma in the Lyon Mountain quadrangle.

Nearly all the aplites of the quadrangle are in the form of more or less well-defined dikes which are very uniform in composition, consisting of white or light-gray potash feldspar, microperthite, and quartz with almost no accessory minerals. In a few cases dark minerals occur in moderate amounts.

Most of the aplite dikes by far lie more or less perfectly parallel to the foliation of the coarse granite, but a considerable number cut across the foliation at various angles. Not uncommonly the cross-cutting dikes are branches of those which are parallel to the foliation. Contacts of the aplites against the granite are rarely sharp, though the transition generally takes place within an inch or two. Some of the aplite dikes, more especially the wider ones, exhibit good magmatic flow-structure foliation. No case of an aplite dike grading into pegmatite was observed, though one example of gradation to silexite was noted. The aplite dikes usually vary from one or two to several feet wide and ten to twenty-five feet long, but some are considerably larger.

The field evidence strongly indicates that all or nearly all the aplites developed during a very late stage of the consolidation of the Hawkeye granite magma, as shown by the common parallelism to the foliation and the lack of very sharp contacts. There is no evidence, such as that above presented, that any of the aplites formed as early as the earliest of the pegmatite and silexite masses, and there is positive evidence that some, and strong probability that many, of the latest pegmatites were intruded after the aplites. Considering the time then during which the pegmatite and silexite masses developed, the aplites are intermediate and the length of time for their development was distinctly shorter. Descriptions of a few selected examples will serve not only to show the nature of the evidence upon which the foregoing conclusions are based, but also to bring out certain other features of interest.

A fine display of aplite dikes may be seen on the ridge one-half of a mile southeast of Hawkeye post-office. Contacts against the typical coarse granite are not sharp, but the transition takes place within an inch. The dikes show all widths up to three feet. Most of them roughly follow the foliation of the granite, but some cut across at low angles and a few at high angles. One dike lies at right angles to the foliation for about fifteen feet and then gradually swings into parallelism with it. A few rods east of this locality some lenses of aplite a few feet long occur with somewhat sharper contacts against the granite. This suggests an earlier development of aplite masses, either as segregation masses or as dikes, which were pulled apart and somewhat strung out in the form of inclusions in the still moderately fluid magma. On the ridge one-sixth of a mile northeast of the first-named locality an aplite dike twelve to eighteen inches wide and exposed for forty feet cuts diagonally across the foliation of the coarse granite without sharp contacts. Almost exactly in its middle there are two masses of silexite fifteen feet long and a few inches wide, with no very sharp contacts against the aplite. This silexite resulted from differentiation practically in the place where it now occurs.

On the eastern summit of Howard Mountain an aplite dike about one foot wide lies parallel to the foliation of and grades into the coarse granite on one side, but it has a fairly sharp contact on the other, this latter contact evidently being a result of some magmatic flowage along the border of the aplite after its development.

On the hill one and one-half miles southwest of Sugarbush post-office a distinctly foliated aplite dike with a maximum width of fifteen feet and traceable for one hundred feet pinches out at one end and everywhere grades into the coarse granite within an inch.

At the top of Averill Peak a number of aplite dikes up to one foot wide lie in the coarse granite parallel to its foliation and without sharp contacts. Some ordinary pegmatites of the late series cut right across these aplites. Several aplite masses ten to twenty feet long occur as lenses without very sharp contacts against the granite.

On a spur of Lyon Mountain one mile east-southeast of its summit a number of aplite dikes from one to two feet wide mostly lie roughly parallel to the foliation of the coarse granite, but some cut across at various angles. These dikes carry some dark minerals, are without sharp contacts against the granite, and are usually foliated parallel to their borders. Several of them contain distinct inclusions of the coarse granite in the form of lenses one or two feet long, without sharp contacts against the aplite and parallel to its foliation. The granite must have been almost or quite solidified before the aplitic magma entered.

One-half mile north of the last-named locality one small aplite dike cuts another without sharp contacts against either aplite or coarse granite. Thus there were two distinct intrusions of aplite not far apart in time.

Conclusions regarding pegmatite, silexite, and aplite in the granites.—Some of the main conclusions from the foregoing observations are as follows:

1. The Lyon Mountain granite and the Hawkeye granite are believed to have developed from a single body of intruding magma.

2. The Lyon Mountain granite contains a great profusion of silexite and pegmatite masses, while the Hawkeye granite contains relatively few.

3. The Hawkeye granite contains many aplite dikes, but none at all was observed in the typical Lyon Mountain granite.

4. By far the greater number of the pegmatites, both the earlier and the later types, consist almost wholly of quartz and alkalic feldspar. With a few local exceptions minerals which indicate the former presence of mineralizers other than water vapor are practically absent.

5. Silexite masses began to develop, probably as segregation products, while the granite magma still possessed a very considerable degree of fluidity, and they continued to form probably both as segregation products and as dikes, until the inclosing granite almost, or possibly completely, solidified.

6. Pegmatite masses also began to develop well before the solidification of the magma, though probably not as early as the earliest silexite masses, and they continued to form until almost, or possibly complete, consolidation of the inclosing granite.

7. The silexite masses represent very siliceous facies of the pegmatitic development, gradations from nearly pure silica to ordinary pegmatite being not uncommon.

8. By far the greater number of the pegmatites, silexites, and aplites occur within the parent granites, though some also occur in the relatively small remnants of the rocks into which the granites were intruded.

9. The aplites were developed during a late stage of the magma consolidation, none as early as the earliest pegmatites and silexites, and probably none as late as the latest pegmatites. Some aplites cut others, thus proving intrusions distinctly different in time.

Authors of practically all the standard works on petrology definitely regard pegmatites as intrusions into the already solidified portions of the magmas from which they were formed. Iddings[1] says that pegmatitic liquid may be made to "flow into openings formed by the fissuring of completely solidified parts of the magma, chiefly the outer portions." According to Harker,[1] "the pegmatite may in any case be regarded as representing the residual 'mother liquor' at the end of the process of crystallization." Pirsson[2] states that pegmatite dikes form "in the already solidified parts of the igneous mass." In an important paper on the origin of pegmatite Crosby and Fuller[3] say: "Pegmatite is the end product or final crystallization of the original magma." Brögger[4] considers certain Norwegian pegmatites as representing the last stage of the consolidation of the granite magma. Such statements as the preceding may hold for many of the pegmatites and silexites of the world, but the writer's conclusions (Nos. 4 and 5 above) regarding the pegmatites and silexites of the Lyon Mountain district are notably different, that is to say both pegmatite and silexite began to develop while the parent magma was still in a relatively highly fluid state.

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[1] J. P. Iddings, *Igneous Rocks*, I (1908), 272.

It is also commonly stated or assumed that pegmatites and silexites always developed in the form of dikes. But from the evidence above presented for the Lyon Mountain district, it is concluded that many of the pegmatite and silexite masses, especially those of earlier origin, developed as magmatic segregation products because they formed while the inclosing granite was still magmatic with a considerable degree of fluidity, and it is difficult if not impossible to understand how pegmatite and silexite in the form of true dikes could have intruded such a magma.

For the comparatively few districts in which silexites have been carefully studied it is commonly held that where pegmatite and silexite have both developed from a granite magma the silexite solidified last. As Iddings[5] says: "The association of these quartz rocks with pegmatite is such that in many instances they appear to be portions of the magma segregated from the rest and the last to crystallize." Spurr[6] reaches the same conclusion after a careful study of the quartz of magmatic origin in the Silver Peak district of Nevada. In the Lyon Mountain district, however, the writer finds that silexite masses began to develop not only well before the consolidation of the parent granite magma, but also apparently even before the earliest of the pegmatites.

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[1] A. Harker, *The Natural History of the Igneous Rocks* (1909), p. 296.

[2] L. V. Pirsson, *Rocks and Rock Minerals* (1909), p. 175.

[3] W. Crosby and M. Fuller, *Amer. Geol.*, XIX (1897), 165.

[4] W. C. Brögger, *Zeit. für Kryst.*, XVI (1890).

[5] J. P. Iddings, *Igneous Rocks*, II (1913), 28.

[6] J. E. Spurr, *U.S. Geol. Surv., Prof. Paper 55* (1906), p. 115.

It is also a matter of common record that pegmatites are either absent from, or relatively uncommon in, their parent igneous body, while they are relatively abundant in the country rocks. Grout[1] has recently cited a number of the many well-known examples. In the Lyon Mountain district, however, pegmatite and silexite masses are extremely abundant in the parent granite, and they are certainly not more common in the relatively small portions of the intruded country rocks which still remain.

Finally many districts show ordinary pegmatite dikes close to or in the granite, and, traced outward into the country rocks, the pegmatites become more and more siliceous, being practically silexite dikes or quartz veins farthest out. As Pirsson[2] says: "Finally passing onward the solution phase might become more pronounced, only silica would be carried, and the dike turn into a quartz vein." Van Hise,[3] in the Black Hills, and Emerson,[4] in western Massachusetts, found pegmatite dikes in schist near granite, and farthest out silexite dikes or quartz veins. But in the Lyon Mountain district such a relationship does not hold, since typical pegmatites and silexites in many places occur side by side in the parent granite, and in some cases both form parts of individual dikes or segregation masses.

PEGMATITES IN THE GABBRO OF THE NORTH CREEK QUADRANGLE

Some years ago the gabbro masses of the North Creek quadrangle were discussed at considerable length by the writer.[5] The very common if not constant close association of pegmatites with the gabbro was then mentioned, but no special study of the pegmatites was made. In 1918 the region was revisited, and the relations of the pegmatites to the gabbro were studied in detail. The gabbro nearly always occurs in the form of stocks or bosses with rounded or elliptical ground plans. The stocks range in length from a few rods to about a mile and in width up to three-fourths of a mile. That most if not all of the gabbro stocks are younger than the syenite-granite series is proved by the many observed sharp contacts often crossing the foliation of the syenite or granite, by many inclusions of syenite and granite in the gabbro, and by some dikes of gabbro which extend into the syenite-granite series.

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[1] F. F. Grout, *Econ. Geol.*, XIII (1918), 180–90.

[2] L. V. Pirsson, *Rocks and Rock Minerals* (1909), p. 180.

[3] C. R. Van Hise, *U.S. Geol. Surv., Mon. 47* (1904), p. 724.

[4] B. K. Emerson, *U.S. Geol. Surv.*, Folio 50, 1896.

[5] W. J. Miller, *Jour. Geol.*, XXI (1913), 160–80; *N.Y. State Mus., Bull. 170* (1914), pp. 26–28.

The field evidence strongly points to the mode of occurrence of the gabbro as pluglike or pipelike forms with nearly vertical boundaries. Much of the gabbro is of the quite typical sort, consisting chiefly of basic plagioclase, some orthoclase, hornblende, and hypersthene, together with almost constant small amounts of ilmenite (or magnetite), biotite, garnet, and pyrite, and some other accessory minerals. An ophitic texture is often well exhibited. Many of the stocks have foliated portions, especially the borders, which are hornblende gneiss or amphibolite.

The pegmatites are mostly coarse-grained, consisting chiefly of potash feldspar and quartz, but with plagioclase important in some cases, muscovite and black tourmaline usually present, and biotite and hornblende not rare. Practically no other minerals occur. The masses of pegmatite exist in all sizes up to two hundred or more feet long and fifty or more feet wide.

Very few of the many conspicuous bodies of pegmatite of the kind just described were observed apart from masses of gabbro in the North Creek quadrangle, and possibly even these few may not be real exceptions, because the adjacent rocks are not always wholly known on account of lack of exposures. Pegmatites of any kind are relatively scarce in the syenite-granite series. Since most or all of the gabbro stocks are younger than the syenite-granite, and since so many of the coarse, acidic pegmatites either cut the gabbros or are at least genetically related to them (see below), it follows that such pegmatites must be distinctly younger than the syenite-granite series. Pegmatites seldom if ever occur well within the larger areas of gabbro, and it seems that they formed as satellites of the gabbro mostly in the marginal portions of the stocks and to some extent at least in the closely adjacent rocks.

There are two features of special interest regarding these pegmatites: first, that they are satellitic developments of rather basic gabbro, and, secondly, that the evidence strongly points to the development of many of them while the parent magma still possessed a considerable degree of fluidity. The following descriptions and figures of selected examples will serve to make clear the principal phenomena of the pegmatites in their relations to the gabbros.

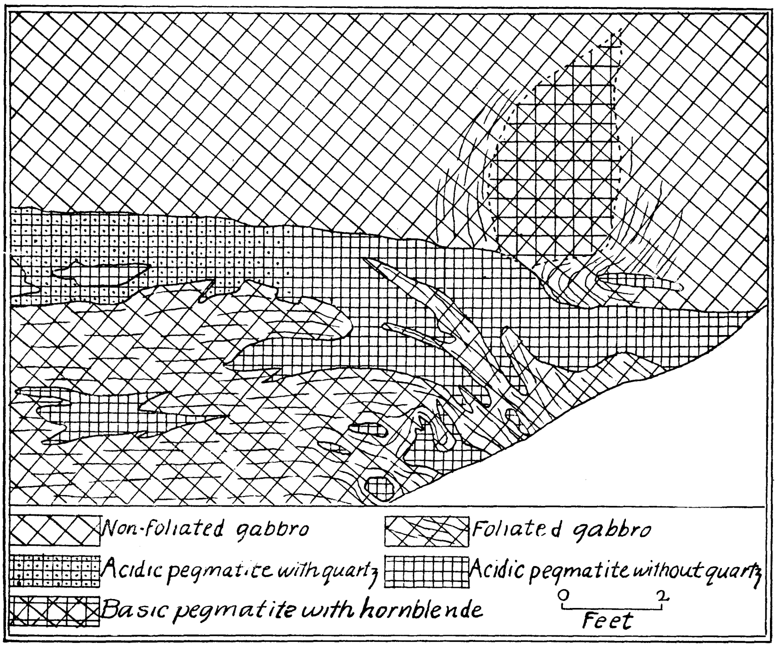
Non-foliated gabbro
Foliated gabbro
Acidic pegmatite with quartz
Acidic pegmatite without quartz
Basic pegmatite with hornblende
0
2
Feet

Fig. 7.—Sketch showing the relations of several facies of pegmatite to gabbro at the northeastern edge of the stock on the hill one mile south-southeast of the Glen in the North Creek quadrangle.

One of the best places in the North Creek quadrangle to study the relation of pegmatite to the typical gabbro is at the top of the hill one mile south-southeast of the Glen. The gabbro stock, which is one-fourth of a mile long, shows a number of pegmatitic satellites, and that it is younger than the surrounding granite is proved by several inclusions of the latter. Figure 7 illustrates the relations of several facies of the pegmatite to the gabbro near the northeastern edge of the stock. Crystals in any of the pegmatite seldom reach lengths of an inch. The acidic pegmatite with quartz carries biotite, and it grades perfectly into the rather acidic pegmatite without quartz but with hornblende. In both of these facies of the pegmatite the chief feldspar is oligoclase to oligoclase-albite. Contacts against the gabbro are usually rather sharp. The more basic pegmatite, which consists chiefly of basic plagioclase and hornblende with some magnetite, shows no sharp contact against either the acidic pegmatite or the gabbro. That the various facies of the pegmatite formed while the gabbro magma was still in a distinctly fluid condition is considered to be proved, not only by the presence of well-defined inclusions of the pegmatite mostly parallel to the magmatic flow-structure of the gabbro, but also by the strong tendency of the fluxion structure of the gabbro to wrap around the inclusions and to conform to the sides of the large body of pegmatite. Quite clearly the molten gabbro intruded and more or less broke up the already consolidated pegmatite which had probably developed as a magmatic segregation mass. The basic pegmatite may have developed somewhat later than the other, as suggested by the lack of anything like sharp contacts against the gabbro, but even this pegmatite formed while the gabbro was still fluid enough to develop a fluxion structure alongside the pegmatite.

Near the middle western edge of the same gabbro stock a pegmatite mass, with a maximum width of twenty-five to thirty feet and an exposed length of about one hundred feet, shows relations notably different from those on the opposite side of the stock above described. Some of the features are brought out by Fig. 8. Toward one side of the general body of pegmatite a mass of practically pure silica (silexite) has imbedded in it many rather imperfect crystals of black tourmaline which mostly range in length from one to ten inches. This small mass is surrounded by very coarse pegmatite made up chiefly of potash feldspar and quartz with a little tourmaline, the feldspars reaching lengths of a foot or more. Inclosing both masses just mentioned is a body of coarse pegmatite, which is the most abundant facies of the rock. The feldspar all seems to be orthoclase in crystals, with maximum lengths of six or eight inches. Quartz is abundant, and hornblende crystals up to several inches long are fairly common. There are also exceptionally fine graphic intergrowths of tourmaline and quartz in masses from a few inches to a foot or more across (Fig. 6C). Along one side of the coarse pegmatite there is a zone roughly five or six feet wide of only moderately coarse pegmatite which consists chiefly of potash feldspar and quartz with some acidic plagioclase and biotite. Adjacent to this moderately coarse pegmatite and forming the outside of the whole mass of pegmatite on one side is a zone several feet wide of moderately coarse pegmatite made up very largely of plagioclase which contains some microcline as graphic intergrowths and a little quartz. This plagioclase zone merges into the true gabbro through a zone about a foot wide. None of the five facies of pegmatite just described are at all sharply separated from each other, and they are very clearly phases of a single pegmatite body. The relation of the pegmatite to the gabbro on the opposite side of the whole body of pegmatite is not so well shown, but there appears to be a gradation within an inch or two. On either side of the pegmatite body the gabbro is nonfoliated. Similar relations to the gabbro are exhibited where the pegmatite body extends fifty feet northeastward, ending in broad tongues in the gabbro. There, however, the plagioclase zone is seven or eight feet wide, and it contains considerable quartz and some biotite. One mass of gabbro five feet across is surrounded by pegmatite with a fairly sharp contact on one side and a gradation on the other.

The assumptions that this whole body of pegmatite was a distinctly later satellitic development of the gabbro than that above described as occurring on the opposite side of the same stock, that the gabbro must have been almost or quite solidified before it formed, and that the five facies of the pegmatite were probably formed by some sort of differentiation practically in the place of their present occurrence are evidenced by the following facts: gradation of the borders of the pegmatite into the gabbro, an inclusion of the gabbro in the pegmatite, lack of magmatic flow-structure foliation in the gabbro near the pegmatite, and perfect gradation from one facies of the pegmatite into another.

Along the northwestern side of the same gabbro stock there are several small pegmatite masses, one with fairly sharp contacts and the other without. Also a number of rather rounded masses of basic pegmatite (chiefly plagioclase and hornblende) from one to several feet across appear to be inclusions, with fairly sharp contacts, in foliated gabbro. Such pegmatite must have formed while the gabbro was still molten. A few rods farther north a small dike of acidic pegmatite with rather sharp contacts has an aplitic offshoot three inches wide which bears off abruptly for twelve feet into non-foliated gabbro, with fairly sharp contacts against the latter.

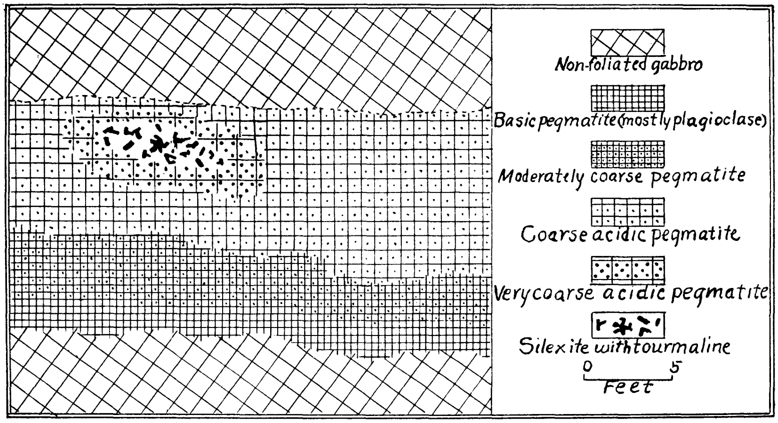
Non-foliated gabbro
Basic pegmatite (mostly plagioclase)
Moderately coarse pegmatite
Coarse acidic pegmatite
Very coarse acidic pegmatite
Silexite with tourmaline
0
5
Feet

FIG. 8.—Sketch showing several facies of pegmatite in the gabbro at the western edge of the stock on the hill one mile south-southeast of the Glen in the North Creek quadrangle.

On the southern side of the small stock one and one-fourth miles north of the Glen several moderately coarse acidic pegmatite masses from three to twelve feet long lie in the gabbro, with fluxion structure of the latter parallel to the borders of the pegmatite, but only close to them. Contacts against the gabbro are rather sharp. Well within the stock several small inclusions of the country rock (granite) also lie in the gabbro parallel to a magmatic flow-structure foliation of the latter. Clearly, then, these acidic pegmatites are not only satellites of the gabbro but also formed, probably by magmatic segregation, well before the gabbro magma was consolidated. Another body of pegmatite about six feet wide in this gabbro grades into a mass of practically pure silica (silexite) four feet long.

A large body of pegmatite exposed for two hundred and fifty feet lies on the east side of the gabbro stock near the top of the hill three and one-half miles south-southeast of Chestertown. This pegmatite is mostly orthoclase and quartz in masses up to a foot or more across, together with considerable muscovite, biotite, and tourmaline in masses up to several inches across. In an old mine pit a moderately coarse facies of this pegmatite containing some plagioclase is intricately involved with a highly foliated feldspar-biotite schist phase of the gabbro which grades perfectly through a fine-grained foliated gabbro into normal, medium-grained, non-foliated gabbro. The zone of mixed rocks, which is forty to fifty feet wide, contains many long lenses, strips, and irregular masses of pegmatite arranged roughly parallel to the fluxion-structure foliation of the schistose facies of the gabbro. Evidently this pegmatite, which developed as an early satellitic facies of the gabbro magma, was more or less broken up and involved with the yet molten gabbro.

Two miles southeast of Chestertown a gabbro stock with highly foliated facies not only contains inclusions of, but also sends dikes into, the granite porphyry country rock. At its north end the foliation of the gabbro perfectly conforms to the rather irregular side of a large mass of pegmatite, which latter is cut by well-foliated, fine-grained gabbro in the form of dikes up to eight feet long, one of these dikes ending in a feldspar-biotite schist. A dike of similar fine-grained gabbro not over six inches wide cuts the granite for thirty feet. In this case it seems certain that the pegmatite must have formed well before the solidification of the parent gabbro, because the pegmatite was intruded by the molten gabbro.

At the top of Hackensack Mountain near Warrensburg a dike of the gabbro clearly cuts syenite, and the fluxion structure of the gabbro conforms to the borders of a small mass of included pegmatite.

Conclusions regarding pegmatites associated with gabbro.—From many occurrences like the examples above described it is concluded that acidic masses ranging from pegmatite rich in potash feldspar and quartz, with or without tourmaline, to pegmatite which is mostly potash feldspar, to pegmatite rich in acidic plagioclase with or without quartz, to basic pegmatite which consists either of basic plagioclase and hornblende or nearly all basic plagioclase, to aplite dikes, and even to nearly pure silica (silexite), developed as satellites of the stocks of normal gabbro. It is also concluded that the development of pegmatite began while the gabbro was still notably fluid, and that it continued until it had almost or completely solidified. Accordingly it seems necessary to regard the earlier-formed pegmatite masses to have developed as segregation masses rather than as true dikes.

It is possible, as maintained by Grout[1] for the Duluth gabbro, that some development of pegmatite may have taken place before the beginning of crystallization of the gabbro magma, but the evidence in the North Creek district is not conclusive. Many of the North Creek pegmatites differ from the Duluth pegmatites in one important respect, namely, that they developed as satellites of the gabbro late in the stages of magma consolidation, some of them probably even after complete solidification.

Such a profuse development of so many kinds of pegmatites from gabbro bodies is not in agreement with the commonly held view as stated by Weinschenk, who says that pegmatites "are relatively rare with plagioclase rocks," and "the more basic the plutonic rock, the simpler are its satellites."[2]

Grout's work on the origin of the pegmatites of the Duluth gabbro and the writer's work on the origin of the pegmatites of the granites of the Lyon Mountain district and of the gabbro of the North Creek district clearly show that many of the pegmatites of those districts are not, as is so commonly stated for other regions, to be regarded as intrusions into already solidified portions of the magma from which they were derived.

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[1] F. F. Grout, *Econ. Geol.*, XIII (1918), 190–92.

[2] E. Weinschenk-Johannsen, *Fundamental Principles* (1916), p. 142.